Suitability of switchgrass (*Panicum virgatum* L.) as a forage crop in the Mediterranean area

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Abstract

In Mediterranean rainfed cropping systems, drought-resistant crops can increase yield and availability of forage during the summer period. In North America, switchgrass (*Panicum virgatum* L.) has been used for decades as pasture and fodder. In Europe, switchgrass has been investigated mainly for its potential as an energy crop. The overall aim of the present study was to analyse the suitability of switchgrass as a forage crop in a Mediterranean environment. A field trial was carried out in Central Italy (Pisa) to evaluate the productivity and nutritive value in mature stands of two switchgrass varieties (Alamo and Blackwell). Alamo reached the maturity for hay harvest (boot stage) in August, about one-month delay with respect to Blackwell. At this stage, the biomass was 13.3 and 7.5 t ha^{-1} of dry matter (DM) in Alamo and Blackwell, respectively. Both varieties produced a summer regrowth harvested in autumn. Nutritive value declined during the growing season due to the increase of fibre and the reduction of protein content. Saponin content significantly differed between varieties and according to the growth stage, ranging from 1.8 to 4.5 mg g^{-1} DM. This study provides useful knowledge to favour the introduction of perennial grasses as forage crops in the Mediterranean, leading to several environmental benefits when compared with the annual species that currently cover half of the forage cropland in Tuscany.

Keywords: switchgrass, rainfed systems, yield, nutritive value, saponins

Introduction

In the Mediterranean environment, extensive and low-input livestock systems need of a sustainable intensification of forage production to increase their economic sustainability, especially in marginal areas. In lowlands, grassland production is limited by climatic conditions that are characterized by an irregular distribution of precipitation during the year; abundant and stormy rainfall in autumn and spring are followed by severe drought condition during the summer, when rainfall is scarce and evapotranspiration is usually high. In this context, the introduction of drought-resistant crops can represent a win-win strategy to improve the forage yield during the summer period (Gherbin *et al.*, 2007). Warm-season grasses have been used for decades as pasture and fodder in North America. During the last decades, switchgrass (*Panicum virgatum* L.) has been investigated in European environment exclusively for its potential as an energy crop in rainfed systems. Recent studies reported that in low-input systems switchgrass was able to increase carbon sequestration and biomass production compared with that of annual crops (Ashworth *et al.*, 2015; Guretzky *et al.*, 2011). However, few studies have evaluated the biomass quality of switchgrass as a forage crop according to the development stage, harvest time and management system (Guretzky *et al.*, 2011). Moreover, although the potential presence of antinutritional compounds such as saponins in fresh switchgrass herbage has been documented (Lee *et al.*, 2009), knowledge about the main variation factors affecting the concentration of saponins in switchgrass is still limited.

The aim of the present study was to assess in a Mediterranean environment (1) the response of two mature stands of switchgrass varieties (Alamo and Blackwell) to a double harvesting system, and (2) to evaluate their suitability as forage crops considering the variation of main qualitative traits (fibre, crude protein and saponin content) during the growing season.

Material and methods

The experiment was conducted in 2015 at the Centre of Agro-environmental Research (CiRAA), Pisa, Central Italy, on five-year-old stands of two switchgrass varieties: Alamo (AL) and Blackwell (BL). From the first year to 2014, both stands were harvested once per year in winter. The average yield, from 2010 to 2014, was 20 t and 15 t DM ha^{-1} yr^{-1}, for AL and BL, respectively. In 2015, AL and BL were harvested in summer at the boot stage (7 July and 5 August for BL and AL, respectively), and the regrowth was harvested in autumn (5 October). At all cutting dates, the aboveground dry matter yield was determined on sampling areas of 1 m^2, in 4 plots arranged according to a split-plot design. In addition, the biomass for qualitative assessment was collected 5 times, T1 (11 May), T2 (4 June), T3 (22 June), T4 (7 July), T5 (5 August, only for AL), from sprouting to the summer harvest, while the summer regrowth was collected only at harvest T6 (5 October). In all biomass samples, dry matter, neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL), crude protein (CP), ash and crude fat (CF) contents were determined by the Van Soest method (1991) and AOAC method (1990). Saponins were extracted according to Lee *et al.* (2009) and the total content was determined by spectrophotometric analysis, with Diosgenin as the reference standard. Data were analysed by a general linear model with switchgrass variety and harvest time as well as their interaction as fixed factors.

Results and discussion

In 2015, the total rainfall during the switchgrass growing cycle, from April to early October, was 280 mm. From April to July the average air temperature increased from 13 to 26 °C, then decreased to 20 °C at the end of September. The sprouting of BL occurred in the first week of April, while new sprouts of AL emerged about 10 days later. BL reached maturity for hay harvest (boot stage) in the first week of July (T4), about one-month before that of AL (T5). At this stage, the above-ground dry matter yield was 7.5 and 13.3 t ha^{-1} in BL and AL, respectively. Similar yields were reported by Alexopoulou *et al.* (2015) for a wintertime single-harvest management. After the first harvest, both varieties produced a summer regrowth, which at the harvest in October (T6) yielded 2.1 and 2.9 t ha^{-1} DM, in BL and AL respectively. The different phenology, observed between the two varieties, could allow a better distribution of the stocking rates during summer period. However, to graze switchgrass during the full growing season, a rotational grazing would be advisable (Burns *et al.*, 2011).

All analysed factors and their interactions affected significantly the quality traits (Table 1). During the growing season, a decreasing nutritive value of forage was observed in both varieties. Crude protein content declined from 10.8 to 2.4 g 100 g^{-1} DM (T1-T5) and from 9.0 to 2.8 g 100 g^{-1} DM (T1-T4) in AL and BL, respectively, while a slight increase of values was recorded at the regrowth (T6). In AL and BL, the NDF content increased from 65.8 and 69.5 to 77.2 and 73.9 g 100g^{-1} DM from T1 to T6. In both varieties, during biomass accumulation, the ADF and ADL content nearly doubled; conversely, CF and ash content declined from T1 to boot stage. The content of CP was significantly higher in AL samples than in BL at T1 and T2. At T1, CF and ash content of BL was higher than AL; conversely, NDF and ADF content was significantly higher in AL. Similarly, at T2 AL samples were significantly higher in CP and ash content, and lower in NDF and ADF than BL. These differences recorded in the first part of the growing season may be due to the delay of the sprouting time between the two varieties. In the regrowth biomass (T6), only the NDF content significantly differed between the two varieties, being higher in AL than BL (57.6 vs 55.5). The switchgrass average CP content at T6 was 3.5 g 100 g^{-1} DM. A higher content of calculated non-structural carbohydrate (NSC) and CF was observed at T6 in both varieties.

Saponin content ranged from 1.8 to 4.5 and from 2.2 to 3.8 mg g^{-1} DM at T2 and T6, in BL and AL, respectively. Significant differences were recorded between varieties at T2, T4 and T6. Similar contents were observed by Lee *et al.* (2009) in other varieties of switchgrass in North America. Although the use of late-summer (T6) regrowth as fresh forage resource would be of interest in rainfed systems,

Table 1. Qualitative trait means and standard error (g $100g^{-1}$ of dry matter) of switchgrass, from sprouting to summer harvest (T1-T5) and at second harvest in October (T6).[1,2]

Harvest	V	CP	NDF	ADF	ADL	CF	Ash	NSC	TS[3]
T1	AL	10.8±0.4a	65.8±1.2b	21.3±2.7b	3.0±0.5	1.6±0.1a	7.3±0.2a	14.6±0.8	2.6±0.1
	BL	9.0±0.2b	69.5±0.6a	28.7±0.4a	3.3±0.4	1.3±0.1b	6.0±0.2b	14.3±0.4	2.4±0.1
T2	AL	6.7±0.4a	70.8±0.4	29.7±0.5b	2.8±0.2b	1.4±0.1	6.8±0.5a	14.3±0.6	2.2±0.1a
	BL	4.9±0.4b	72.5±0.6	35.9±1.0a	3.9±0.3a	1.2±0.1	6.0±0.2b	15.4±0.4	1.8±0.1b
T3	AL	3.6±0.1	72.2±0.2	37.6±0.5	3.8±0.2b	1.1±0.1b	5.7±0.1a	17.5±0.2	2.5±0.3
	BL	3.7±0.3	72.7±0.3	37.4±1.1	5.1±0.1a	1.4±0.3a	4.9±0.3b	17.3±0.6	2.9±0.1
T4	AL	3.0±0.1	73.7±0.9	39.0±1.5	5.8±0.5	0.9±0.1	4.2±0.1	18.1±0.8	2.2±0.1b
	BL	2.8±0.1	73.9±0.1	38.6±1.0	6.2±0.3	0.8±0.1	4.2±0.1	18.3±0.4	2.7±0.1a
T5	AL	2.4±0.0	77.2±0.8	42.8±3.1	7.9±0.4	1.8±0.1	3.2±0.1	15.6±0.8	2.7±0.1
	BL	-	-	-	-	-	-	-	-
T6	AL	3.3±0.3	57.6±1.1a	30.2±0.6	1.7±0.1	2.0±0.1	6.6±0.1	30.5±0.6	3.8±0.3b
	BL	3.8±0.1	55.5±0.7b	29.1±0.7	1.6±0.1	2.2±0.1	6.9±0.2	31.6±0.5	4.5±0.2a

[1] NDF = neutral detergent fibre; ADF = acid detergent fibre; ADL = acid detergent lignin; CP = crude protein; CF = crude fat; NSC = non-structural carbohydrates; TS = total saponin.
[2] For each harvest dates and trait different letters indicate significant difference for Tukey's test ($P<0.05$) between varieties (V).
[3] mg g^{-1}.

the high content of saponins in switchgrass regrowth suggests the need to avoid grazing, especially by small ruminants (Lee *et al.*, 2009). Further studies are needed to investigate the effect on animal health of saponins in the fresh biomass of switchgrass. In conclusion, in several parts of Mediterranean region, annual forage crops are currently used to produce high quality fodder or pasture, but their use is associated with increasing feeding costs, risk of soil erosion, and loss of soil organic matter due to annual soil preparation and sowing. This study provides useful knowledge to promote the introduction of a perennial species in crop rotation because of its capacity to guarantee satisfactory yield levels and, at the same time, to conserve soil fertility.

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